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Heating Soft Crab Shedding Systems

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Introduction

The molting of blue crabs, and ultimately soft shell crab production, is regulated by water temperature. A certain threshold or minimum water temperature must be reached before blue crabs begin to molt (shed). Although crabs begin shedding at temperatures in the mid-60'sF (18-19°C), water temperatures near 70°F (21°C) are optimum for active shedding. As the water temperature increases, the time required for a crab to progress through the stages leading to molting decreases (the time needed to go from a white-line, to a pink-line and finally red-line crab). The time needed for a complete molt--for a soft crab to exit from its old shell--also decreases with increasing water temperature.

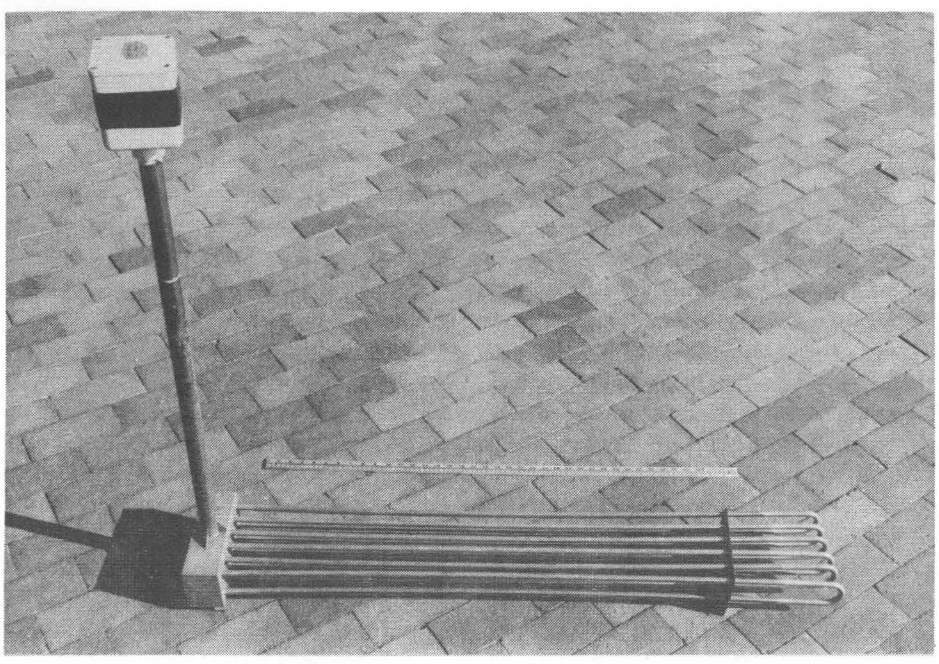


Figure 1. This 27,000 watt titanium immersion heater was used to heat the water in a 4000-gallon recirculating water shedding system. Reference ruler is one meter long.

In the Chesapeake Bay, operators of recirculating water systems for soft crab production can experience problems during the early part of the shedding season (mid-April through May) because of too cool or fluctuating water temperatures. During this time natural air temperatures can fluctuate widely between day and night and as a result of weather changes. In most cases, the water temperature within a recirculating system is dependent upon the temperature of the surrounding air and, thus, is also subject to temperature variations. The specific problems caused by fluctuating water temperatures relate directly to the conditioning of biological filters and the length of time required for crabs to shed.

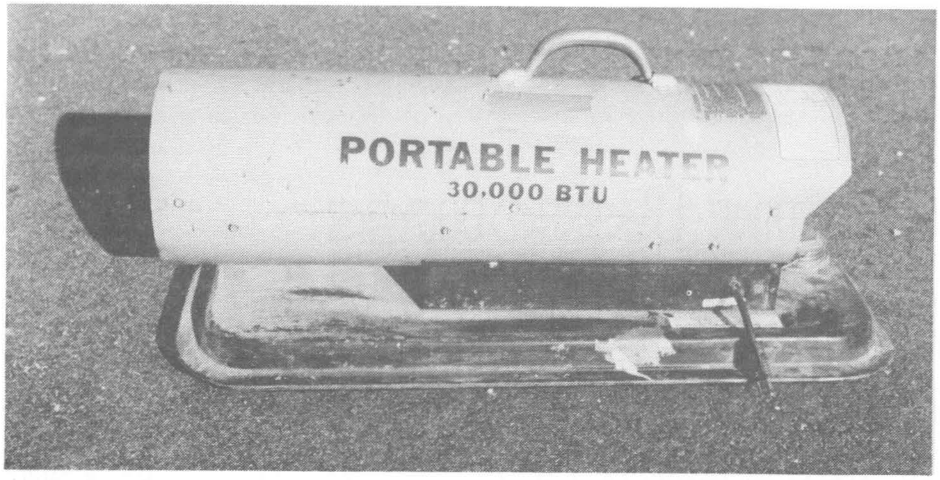


FIGURE 2. A propane-fired heater with an air-blower,similar to this unit, was used to heat the water in a 4000-gallon recirculating water shedding system.

The proper conditioning of the biological filter within a recirculating system is critical to the overall efficiency of the system. Improper or "under" conditioning of the biofilter results in a lower carrying capacity of the production system or outright mortalities of crabs within the system. Even at stable temperatures the conditioning of the biofilter is a slow process, requiring 3 to 4 weeks. Fluctuating water temperatures can prolong the conditioning response even longer. Lowering the water temperature by as little as 2°F (1°C) has been shown to slow the oxidation rate of ammonia by 30% within seawater aquaria.

Already mentioned was the effect of lowered water temperatures on crab shedding rates. During the May "spring run," soft crab producers can expect large numbers of pre-molt (peeler) crabs. In order to get the best financial return, the soft crab producer must hold as many crabs in a shedding system as possible at one time and turn over the number of crabs in the system as quickly as possible. Cool or fluctuating water temperatures reduce the operator's potential profit by either not permitting the operator to hold a full compliment of crabs because of a poorly conditioned biofilter, or by reducing the turn-over rate within shedding tanks. Realizing these problems, various options for water temperature control (heating) were investigated.

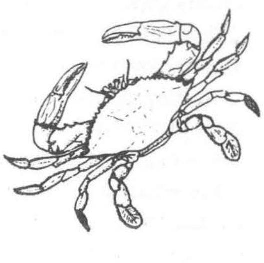
Heating Methods

There are three basic methods by which water may be heated: 1) directly, the water itself is heated; 2) via heat exchangers, heat is transferred from another source to the water; or 3) passively, the surrounding air is heated. With direct heating the water itself is normally heated using a thermostatically controlled immersion unit. This type of heating has a very high heat transfer efficiency. Since the heating of water involves moving a considerable amount of energy, the more efficient the heating device the lower the amount of input required to raise the temperature. This value will always be less than 100%.

Heat exchangers use a "working" fluid in a closed loop as a heat carrier to transfer heat to the desired water. The most common source of "heat" is an oil or gas-fired boiler. These systems are exceptionally reliable. While heat exchangers are commercially available in a wide range of sizes, they are also easily constructed of readily available parts.

Passive or air heating relies on heating the air surrounding a closed system and transferring heat to the water by convection. This type of heating can be further characterized as "active" or "passive." Active air heating involves heaters with air blowers to induce circulation patterns; these are usually thermostatically controlled. Passive air heating would be similar to a greenhouse type structure where natural heat (sunshine) is utilized. There are any numerous combinations of these two methods.

The methods used for heating recirculating shedding systems take on many forms but basically entail either heating the water or air in the system. Some of the heating systems used by Virginia soft crab producers have included thermostatically controlled immersion heaters, oil or gas-fired swimming pool heaters or boilers, gas-fired air heaters (blowers), electric air heaters, kerosene heaters and solar collectors. Many questions remain as to which are the most efficient or most practical to use.



Heating Systems

During May 1989, several means of heating shedding systems were evaluated. Within one facility side-by-side comparisons of an in-water electrical immersion heater (Figure 1), a propane-fired heater (Figure 2) with an air-blower, and no heat at all were made. This facility was housed within an unheated building and consisted of fifty 4' by 8' shedding tanks. These fifty tanks were actually three independent systems, two with twenty tanks (approximately 4,000 gallons of water) and one with ten tanks (approximately 2,000 gallons of water). The basic configuration of all three systems was identical, with the exception that the ten tank unit had a smaller biological filtration system than the twenty tank units. It was essentially half the size of the twenty tank systems.

One twenty tank system was supplied with a thermostatically controlled 27,000 watt (27kw) electrical immersion heater with a titanium heating element. This size heater required special wiring because of the high amperage required for its operation (123 amps). The heating element itself cost $683 (Glo-Quartz Co.--mention of trade names does not constitute endorsement) and the indicating thermostat cost $572. For practical applications, a much less expensive thermostat can be purchased from electrical supply outlets.

The second twenty tank system was heated using a propane-fired air blower ("bullet" heater) with thermostatic control. Since this system heated the surrounding air to raise the water temperature, it had to be isolated from the remainder of the building. This was accomplished by installing a false ceiling of plywood and using heavy plastic sheeting between systems. The propane heater was purchased locally for under $200.

The third system of ten tanks was left unheated. While the water volume in this system was half the other systems, it served as an approximation of what could be expected in an unheated system of twenty tank size. Other closed systems in the region with 16-20 unheated tanks, behaved like the ten tank unit at this facility.

Heating Costs

Figure 3 shows the daily water temperatures for the two heated systems, beginning on April 12. For the next eight days the temperatures of the two systems were essentially identical. While a general warming trend was observed, there were fluctuations that occurred on a daily basis. These fluctuations corresponded to daytime heating and nighttime heat loss within the systems.

On April 20, the propane heating system was put into operation. The water temperature in this system increased 8°F (4.4°C) overnight, while the other system continued its pattern of daily fluctuations (sometimes as much as 2°F). One week later (April 27), the electrical immersion heater was installed. In the space of a few hours, water temperature was raised 7°F (3.9°C) to 70°F (21°C). After two days of adjusting the thermostat, the immersion heater system stablized around 68°F (20°C).

An important question to ask about these two heating units is how much it cost to operate them. The electrical immersion heater was in place for almost 33 days (789 hours). During that time the heater actually ran only 60.4 hours, or just about 7.7% of the time. Based on the electrical rates in effect during that time the cost to operate the heater was $107.61 or about $3.26 per day. Given the price soft crabs were selling for then, that works out to two or three soft crabs per day to operate the heating system.

The propane system was similar in operating expense. Over a 30 day period approximately $100 worth of propane was burned, or about $3.33 per day. Again, it requires two or three soft crabs per day to pay operating expenses.

The major cost difference in the two heating systems was in the initial expense and installation. The immersion heater and control unit were over six times more expensive than the propane heater. This does not take into account the special wiring necessary for the immersion heater installation. The immersion heater had an operating voltage of 240 volts at an amperage of 123 amps. It took an electrician and helper one full day to do the required wiring for this heater. The heavy electrical wire also added several hundred dollars to the cost. As it was, when the immersion heater kicked on, the lights in the shedding house dimmed. (In all likelihood, a smaller heater could have been used just as effectively.) The propane heater required no special installation and was done by the shedding facility operator. Regardless of the heating method used, it is important that the entire shedding system be enclosed.

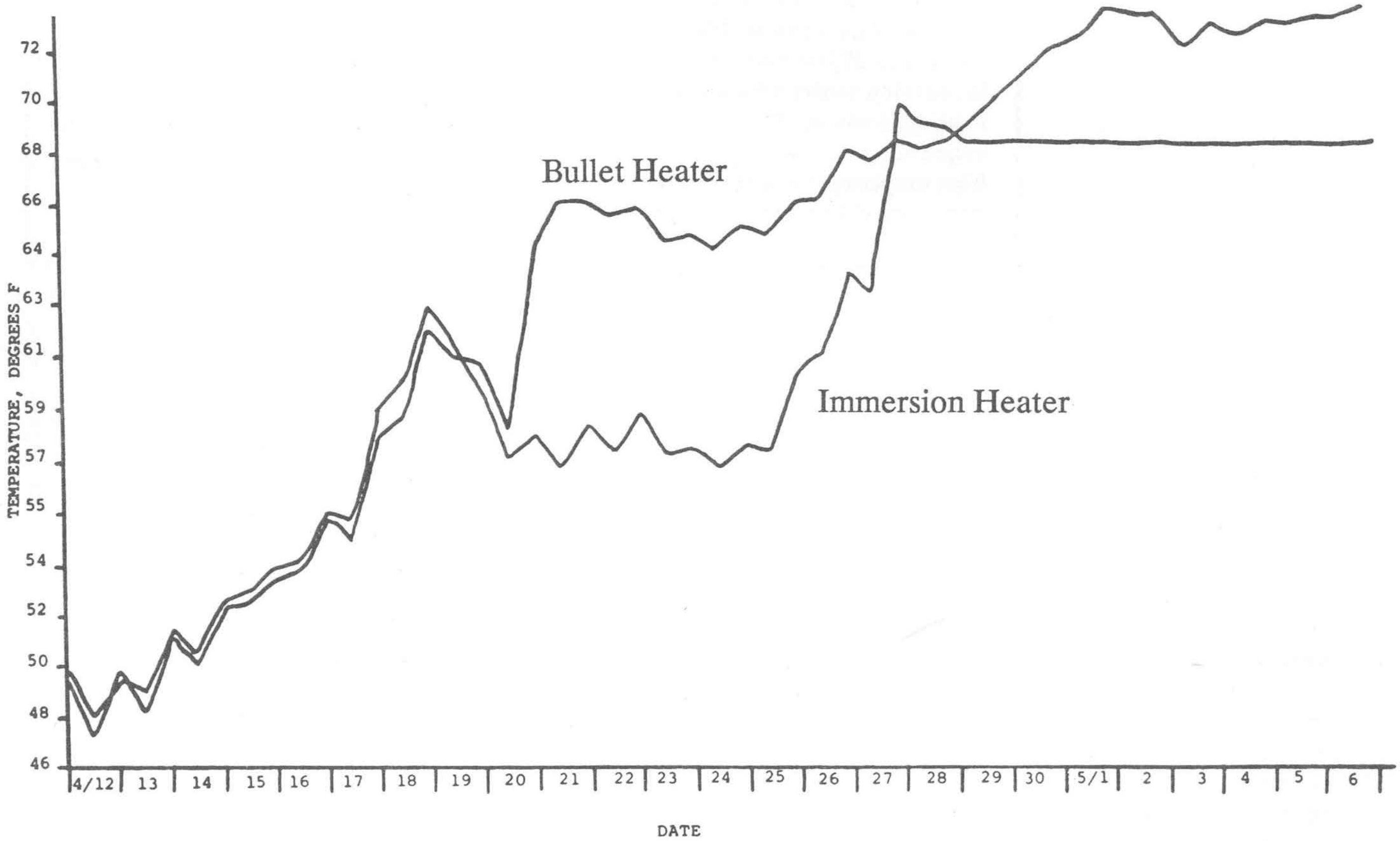


Figure. 3. Daily water temperatures for the two heated systems.

Nutrient Analysis

Figure 4 contains several data sets of interest. It presents concentrations of ammonia and nitrite, compounds potentially toxic to soft crabs, as determined two ways. One measurement, with no parentheses, was determined very precisely in the nutrient analysis laboratory of the Virginia Institute of Marine Science. The other measurements, within parentheses, were field determinations using a commercially available colormetric test cube. These duplicate data sets were taken for two reasons: to establish the accuracy of the field test kit and, to provide the producer with real-time estimates of biofilter condition so the producer could regulate/allocate peelers to different systems.

While there were times when the laboratory and field determinations differed widely (see 5/1 under System I), the correspondence of the two methods was good. Of particular interest was the correspondence when the levels of ammonia and/or nitrite approached the potentially dangerous points (problems could be expected when either nutrient occurred in concentrations over one part per million). As a rough indication of potential problems (i.e. crab mortality) the color cubes are reliable and cost-effective.

Figure 4. NUTRIENT ANALYSIS/PEELER LOAD

DATE	SYSTEM I (PROPANE)			SYSTEM II (IMMERSION)			SYSTEM III (NO HEAT)		
	Ammonia (ppm)	Nitrite (ppm)	# Peelers	Ammonia (ppm)	Nitrite (ppm)	# Peelers	Amnmonia (ppm)	Nitrite (ppm)	# Peelers
4/27	0.8	0.3	1200	0.5	6.1				
	(0.2)	(0.2)		(0.2)	(o.s.)*		(0.2)	(o.s.)	
5/1	0.8	1.0	3600	0.1	2.4				
	(0.2)	(0.4)		(0.2)	(1.0)		(0.2)	(o.s.)	
5/3	2.9	2.2	4800	0.2	0.7	2100			
	(0.2)	(1.0)		(0.2)	(0.4)		(0.2)	(0.5)	
5/5	0.9	4.4	3000	0.3	0.8	3300			
	(1.0)	(o.s.)		(0.5)	(0.4)		(0.2)	(1.0)	
5/8	0.4	0.4	3600	1.9	3.8	4200			
	(0.3)	(0.2)		(o.s.)	(o.s.)		(0.2)	(0.2)	
5/10	0.5	0.7	3600	1.0	7.1	4800			
	(0.8)	(0.4)		(0.8)	(o.s.)		(0.2)	(0.2)	
5/12	0.5	0.5	4800	0.5	1.5	3900			1500
	(0.6)	(0.4)		(0.6)	(0.8)		(0.4)	(0.4)	
5/16	0.7	0.4	5700	1.3	1.2	5100			2700
	(0.8)	(0.2)		(1.0)	(0.8)		(o.s.)	(o.s.)	
5/18	1.1	0.4	6000	1.7	1.6	6000			2100
	(0.6)	(0.2)		(1.0)	(1.0)		(0.8)	(o.s.)	
5/22	0.6	0.3	4800	1.0	0.7	4500			2700
	(0.6)	(0.2)		(0.6	(0.4)		(0.8)	(1.0)	
5/24	1.1	0.2	3000	0.7	0.3	3600			2700
	(0.4)	(0.2)		(0.6)	(0.3)		(0.4)	(0.6)	
5/26	0.4	0.1	3300	1.0	0.3	2700			2100
	(0.2)	(0.2)		(0.8)	(0.2)		(0.4)	(0.2)	

* Off measurement scale

The Final Product!

Cost Return

Because of record keeping constraints only an estimate of weekly peeler load can be given (Figure 4). This was done to prevent the possibility of double or triple counting of peelers and hence overestimating soft crab production. Soft crab production was estimated using a very conservative survival estimate of 90% (Figure 5). In the thirty day period, System I handled approximately 18,550 peelers, producing 16,695 soft crabs (1391.25 dozen). For the same time, System II handled 16,150 peelers and produced 14,535 soft crabs (1,211.25 dozen). The difference between the two systems was 180 dozen, and can be directly related to be capability of the system to receive peelers. System I was heated one week prior to System II and began producing soft crabs one week

Figure 5. ESTIMATED SOFT CRAB PRODUCTION, 27 APRIL 89 -- 26 MAY 89

	SYSTEM I (PROPANE)	SYSTEM II (IMMERSION)	SYSTEM III (NO HEAT)
Week 1	1,080	-------	-------
Week 2	3,420	2,430	-------
Week 3	3,600	3,870	1,350
Week 4	5,265	4,995	2,160
Week 5	3,330	3,240	2,250
	16,695	14,535	5,760
Soft crabs per shedding tank	834.75	726.75	576.0

before System II. System III (unheated) was begun on April 10, but by May 16 it was still not ready to be heavily loaded because of high (off scale) readings of both ammonia and nitrite. Unfortunately, because of peeler abundance the producer needed this tank space. In order to compensate for the inability of System III to handle the peeler load, the producer had to make partial water exchange every two days for almost two weeks.

Soft crab production on a per tank basis better shows the economic benefits to heating shedding systems (Figure 6). Over the five week experimental period a single tank in System I yielded 834.75 soft crabs. For the same period, a tank in System II yielded 726.75 soft crabs, a difference of 108 fewer soft crabs than System I. Even greater production disparity occurred between System I and System III: System III yield only 576.0 soft crabs per tank, 258.75 fewer than System I. These differences in production can be put on an economic basis by using a conservative sale price estimate of $1.25 per soft crab ($15.00 per dozen). A tank in System I would return $135 more than one in System II, or $323.44 more than one in System III over the five week period. Even if initial heater cost and operational expenses are considered, the heated systems outperformed the unheated system and System I still provided the best economic return (Figure 6). At these values the advantages of heating a shedding system become very apparent.

In summary, the early season heating of recirculating water shedding systems is beneficial on two counts: it aids in biofilter conditioning and allows high production during a time when soft crab prices are high. Heating can be accomplished at reasonable costs and should be included in all closed systems. These two methods are by no means the only way to heat shedding systems. Other techniques can be equally successful and cost-effective.

Figure 6. Summary of production and cost/return information.

	System I (Propane)	System II (Immersion)	System III (No heat)
Equipment cost and installation per tank	$ 10.00	$ 75.00	0
Operating cost per tank	5.00	5.38	0
Subtotal	15.00	80.38	0
Soft crabs produced per tank	834.75	726.75	576.00
Value per tank @ $1.25/crab	$ 1,043.44	$ 908.44	$ 720.00
Return per tank minus costs	$ 1,028.44	$ 828.06	$ 720.00

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